Vol. XXXV. JULY, 1896.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

No. 772.

NOTES UPON THE CONSTRUCTION OF A WATER SYSTEM FOR PLACER MINING, AND SUGGESTIONS FOR A NEW METHOD OF DAM BUILDING.

By Robert Brewster Stanton, M. Am. Soc. C. E.

Presented November 6th, 1895.

WITH DISCUSSION.

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rich placer gravel is found in the well defined channel of an ancient river bed, which was elevated as the mountains rose, and left high and dry upon the summit of the ridge. It is not the intention to go into the geology of this region, nor into its ancient history, except so far as it bears upon the engineering features of the work.

The general course of the old river, at the point under consideration, was nearly southwest. Coming as it did from the north or northeast, it left, with perhaps other gold-bearing streams, deposits of auriferous gravel scattered over the Mojave Desert, and had its mouth some 10 to 15 miles south of San Antonio Peak, when the great San Gabriel Valley, in which is the town of Pasadena, and also the country around Los Angeles, were still under the waters of the ocean. Whether these southern rivers were the lower portions, and whether here were situated the mouths of part of the great ancient river system of the North, which has produced so much placer gold, it is not necessary for present purposes to consider. Yet it is interesting to observe some of the well defined river mouths on the southwest slopes of the ranges in southern California, where gold-bearing gravel has been deposited over thousands of acres, to a depth of from 300 to 500 ft., in well defined ocean bays. This gravel is mixed with all kinds of marine shells, some immense oyster beds in these deposits now lying from 2 000 to 3 000 ft. above the present sea level, and it may not be out of place to note, as has been demonstrated from well authenticated documents, that the first discovery of gold in California was made in one of these bay deposits, that of the San Feliciana, in Los Angeles County, about 40 miles north of the city of Los Angeles, by Francisco Lopez, from six to sixteen years before the much glorified Marshall made his discovery in 1848 at Sutter's Mill.

Topographical Features.—The topography of that portion of the ridge on which the old channel was raised has almost entirely changed during the ages since the upheavals. The elements have worn away the greater part of the old channel. There are recent gulches cut across and parallel with the old stream, and most of the country surrounding its course lies below the present level of its bed-rock. In three places the old bed is left. One is where it passes through a gap between two hills, and both banks of the river are left with the gravel some 80 ft. deep between them. In another but one bank and a portion of the bottom rock remains on the steep side of the mountain.

The third is a level piece of the bed-rock, with deep gulches on every side, and this capped with a cone of gold-bearing gravel; while in the long gulch, that has cut diagonally across the old river, has been formed a secondary deposit of gravel and gold, washed down from the channel above.

The Water Supply.—Although other things are required, the one essential for the operation of placer mining is plenty of water. While, as remarked, the gravel was left high and dry, a water supply had been provided by Nature about 2.5 miles distant under the summit of San Antonio Peak. On the south side of the range, at some previous time, the side of this mountain slid down toward the sea, leaving a tipped-up basin with apparently a solid rock bottom and with high mountain walls on all sides save one, and covering an area of some 1 200 to 1 500 acres, the lower edge of the basin being about 2 200 ft. below the summit of the mountain. This basin has been gradually filled with débris from the mountain above, consisting of broken rock and earth, and part of its surface is now covered with heavy timber.

Although within sight of the orange groves of Pomona and Ontario, some 15 miles distant, in the valley below, these mountains are covered over six months in the year with heavy banks of snow. The weather is not severely cold during the whole of the winter, yet at an elevation of 8 000 ft. the author has experienced storms of snow and wind as severe and almost as cold as any in the higher elevations of the Rocky Mountains or in the Dakotas. Into this great basin, the snows drift and pack during the winter, and even under a southern California sun remain until late in July. At the lower edge of the basin, at the head of San Antonio Creek, burst out springs, which form the source of the water supply for the mines.

The Reservoirs and Pipe Line.—The water from these springs flows over the bed-rock at the lower edge of the basin, drops into the gulch at the head of San Antonio Creek, and sinks into the débris that fills the gorge. To catch this water and turn it into the head of the pipe line a small reservoir or catch basin was built.

The débris was simply leveled off across the gulch, about 60 ft. wide, leaving a bottom of fine broken granite rock, with the rock walls of the hill on three sides, two of these sides being slate and the upper or back granite. On one side this bottom was sunk 3 or 4 ft. deeper for a waste and cleaning gate.

At the lower or outer side of this collecting reservoir were two large granite bowlders. From a notch cut in the slate wall a pine log dam 6 ft. high was built across to the bowlders and to the opposite wall, lined with a double thickness of plank sunk into a trench in the débris, and the fine broken rock filled back against the plank. A waste gate was left through the dam at the lower corner opposite the pipe entrance.

In considering the methods of construction of this whole work, the fact must be borne in mind that the body of gravel to be hydraulicked, while rich in gold per cubic yard, is of limited extent, and will all be washed out and the works be of no value in a very few years, and hence plans and methods were adopted for some parts of the work not suited to more permanent structures. The head of the pipe was run through the planking between the logs, with a strainer on the end to keep out leaves and sticks.

It will be seen that in this small basin there were five kinds of material to be variously joined together by a water-tight lining; shattered slate to be joined to the solid granite and to the plank dam; the bottom of finely broken stone, after being well rammed, to be covered and joined water-tight to slate, granite and planking, and the planking to be joined to the iron pipe. This was done by covering the whole inner surface with two coats of thoroughly prepared asphalt paste, applied hot. After the small holes, cracks and crevices were filled, the thickness of the asphaltum was not over 0.5 in.

This asphalt paste was made of 4 parts of the very best refined California asphaltum and 1 part of crude petroleum, without sand, boiled together until when cool it formed a tough rubber-like paste, brittle under the hammer when absolutely cold, and yet elastic and pliable with the least warmth, adapting itself to any slight change in foundation or walls. A tough rubber-like pouch resting inside a frame of rock and timber was thus formed. With this lining a perfect joining was made between slate and granite, timber and rock, gravel and plank, plank and iron, and, after two summers and one severe winter, is in good condition and well adapted for the uses intended, the only repairs being the addition of a few quarts of asphalt last spring. Further reference to this work will be made in the description of the pressure reservoir.

The Pipe Line.—The distance from the collecting reservoir to the pressure reservoir or penstock, just 2 miles, was along a very steep, rough and crooked mountain side. It would have been impracticable

to maintain a ditch or flume on account of the snow and rock slides from the mountains above. For this reason, and also on account of the nature of the material along the route, a pipe line was laid. A bench from 2.5 to 4 ft. wide was cut along the mountain side, and in this, next to the wall where the material was earth or débris, was sunk a trench in which was laid the pipe, but along the cliffs and in solid rock the whole bench was cut out to the bottom level of the trench. For a distance of some 200 ft. at one point, a half tunnel was cut in the face of a perpendicular cliff.

One feature of this work is worthy of note, as causing extra expense in construction. On account of the rock and snow slides from above, it was necessary to cover completely this pipe for protection, and owing to the very steep mountain sides almost every particle of the material excavated was lost in the ravines below. Hence to cover the pipe new material had to be excavated, and this, especially along the rock faces, increased considerably the expense of the work.

At three points the pipe is exposed in carrying it across steep and narrow gulches, this plan being considered cheaper at these places even if the line had to be replaced, and extra pipe was provided and left on the ground for that purpose. Across these gulches were built simple lattice spans 32 and 64 ft. in length, resting on trestle bent abutments. The spans were built of rough mountain pine lumber, the top and bottom chords being composed of one line of 2 x 12-in. plank faced with two lines of 1 x 12-in. boards breaking joints, and latticed and braced with 1 x 6-in. boards all simply spiked together with wire nails. The 64-ft. span was 6 ft. in height and 4.5 ft. in width, all of the material like the pipe, being transported for nearly 2 miles on men's backs, as is described a little farther on. This method of construction, though rough and in some respects unscientific, has for two years proved entirely satisfactory for the purposes intended.

The pipe laid was the ordinary California No. 16 gauge sheet iron riveted pipe boiled in asphalt, with driven joints. It was laid on a grade of 40 ft. per mile for the first 500 ft., the remainder being on a grade of 16 ft. per mile, except the last 1 500 ft., which was 26.4 ft. per mile.

The first 1 800 ft. of pipe was 12 ins. in diameter, 2 000 ft. was 10 ins., and the balance was 8 ins. in diameter. Cross and waste valves were provided at the upper and lower ends and at the head of the 8-in.

pipe. Air valves were placed about 1 200 ft. apart along the whole length of the line. After careful examination of the gulches to be crossed, etc., it was estimated that the pipe could be laid more cheaply on such a continuous grade, and it could be completely emptied of all water in winter without the use of so many expensive valves as would have been necessary if the gulches had been crossed by descending into them. It may here be remarked that the size of this pipe did not meet the approval of the author on account of the fact that, although it carries all the water coming from the springs in August, September and October, it allows about two-thirds of the water flowing in April, May and June to go to waste. The capacity of the pipe should have been such as to carry nearly all of this early melting snow, so as to work the mines at the greatest advantage and to the full capacity of the water during the early months, thus getting maximum results for the whole year. But he was overruled by the treasurer of the company on account of first cost.

The pipe, valves, material for laying the pipe, timber for dam and bridges, and asphaltum for reservoirs were all delivered by wagon at the lower end of the pipe line. In order to distribute this pipe along the line, and the material for the small reservoir and bridges, resort was had to primitive means of transportation. The weight of all this material, including the pipe from the penstock to the mines, was approximately 100 tons. This 100 tons had to be carried on men's shoulders to an average distance of 1.25 miles along a narrow path on this steep mountain side and around cliffs where a mis-step would have dashed men and load upon the rocks hundreds of feet below.

Although the author has had some experience with the French Canadian voyageurs in the pathless forests north of the Canadian Pacific Railroad, and in portaging heavy supplies around portions of western rivers, it had never fallen to his lot to experience the difficulties or expense of transporting in this primitive manner 100 tons of bulky material even the short distance of 2.5 miles, especially over such a steep side hill trail. When the time drew near to begin this part of the work the grading of the line was about three-quarters done and it would have been inconvenient to lose the grading force. There came near being a rebellion among the men upon this work, for the ordinary grader objected to being turned into a pack mule.

One of the foremen was sent down to secure the aid of some Mexi-

can Indian packers. A dozen of them were brought up and set to work. They worked all of one day and then, with two exceptions, vanished down the mountain during the next night without asking for their day's pay. A second attempt was more successful, and a larger band of Mexicans was secured, that remained to complete the work. After several days' trial, with a young engineer who spoke Spanish as a foreman, it was concluded that they were doing good work when two men carrying one piece of pipe between them made an aggregate of 16 miles per day over such a trail, that is, 8 miles out loaded and 8 miles back empty. The largest pieces of pipe weighed 210 lbs. each. It was thought then, to save the expense of the foreman, to set these packers a task, a custom followed largely in handling Mexican workmen. Sixteen miles a day was taken as a basis. The next day they began with this task and they were comfortably seated around their camp fires by three o'clock in the afternoon, working in this way. Two of the men would take between them a piece of pipe weighing 210 lbs. and trot along from 0.5 to 0.75 mile without stopping. The heaviest work was packing the 12-in. cast-iron gates to the outer reservoir. After taking them apart, the largest pieces weighed 425 lbs.; these had to be carried in the same manner over the same trail the full 2 miles. Four men went with each piece at one time. Two of them would carry it swung between them on a pole on their shoulders from 500 to 1 000 ft. according to the nature of the trail, and then give it to the other two, thus alternately carrying it the 2 miles.

It is rather a remarkable fact that on the Pacific Coast where so much of this light sheet-iron pipe is used, that manufacturers have not made a much lighter water gate to go with it. Nowhere among the large pipe manufacturers in San Francisco could anything be found for water gates except the ordinary cast-iron gates used with heavy cast-iron pipe.

One of the most difficult parts of the work in laying this pipe was where the line passed over an immense rock slide that came from 1 000 ft. above the line and extended as many more below. The top 10 to 15 ft. of the slide was the only portion that kept gradually sliding. After moving hundreds of tons of this material the ditch seemed just as far from completion as when it was begun. The plan was then adopted of running in the trench for one length of pipe, 20 t., covering that up completely to the natural slope of the slide, and

then excavating for the next section independently, allowing the loose material, with some assistance from the men, to form a rough arch up into the slide above that portion being excavated; in this manner the pipe was successfully laid, a section at a time, down in the more solid portion of the slide, that apparently had not moved for years. It was dangerous work, for in driving the joints the heavy blows of the maul shook the whole slide. The author stood on the bank and watched the movement of the slide while the workmen were down in the ditch, and many times had to give the alarm for the men to jump for their lives. It may be remarked, however, that the whole work of this water system was completed without the least accident to any of the men.

In covering up the pipe through this slide the covering stones were selected and laid so as to form a complete dry arch over the pipe. Last winter entirely obliterated the line of work on top of the slide, but after nearly two years the pipe itself is apparently in perfect condition.

The Pressure Reservoir.—This reservoir was built for two purposes: *First*, as a penstock at the head of the pressure pipe to the mines; *second*, as a reservoir to hold the water for some hours, during the latter part of the season, when the supply was limited. It is not the size or capacity of this reservoir that calls for special attention. Very small results, if they demonstrate principles, may be more instructive than larger enterprises with questionable outcomes.

Plans were made for a larger reservoir, but only the bottom portion was built with a capacity of some 330 000 galls., while if completed to its full height the capacity would be 3 000 000 galls.

This reservoir was formed at the head of a gulch on a thickly timbered part of the ridge above the mines. A semi-circular dam was built across the gulch, of a single thickness of large pine logs, with ends sawed on radial lines and butted close together, forming an arch with a slight batter up stream. Each row of logs was separated with, and bound together by, smaller logs laid at right angles to the dam and extending up into the reservoir. As these were put in place, a bank was formed on the upper side of the timber, of earth and broken rock well tamped in around the logs. This material came from cleaning out the gulch to form the bottom of the reservoir, and was tamped in dry (there was not a drop of water within a half mile) no

attempt being made to form a water-tight or water-holding dam of this material. The slope on the upper side of this dam was one and one-half to one, that on the sides of the reservoir being two to one for convenience, not from necessity. The depth of the bottom portion of the reservoir built was 12.5 ft.

It may be explained here that in order to form the larger reservoir of 3 000 000 galls. capacity, a large amount of material would have to be excavated from the sides. This material, broken rock and earth, it was intended to dump over the present dam, and tamp in layers between the present and a second log dam and crib built farther down the gulch.

The use of these log dams in the manner described was to save expense in handling sufficient material to form an ordinary earth or rock dam, and, as remarked before, would not be adapted to structures intended to be permanent.

In considering the next part of the subject, the most important item of all, the water-tight lining of such a reservoir, the method of constructing the dam bears an important relation to the material used for lining. In this portion of the work, the building of the dam and reservoir proper, it is thought that the plans followed are applicable to dam and reservoir construction for permanent works of almost any size, with proper modifications of details for local conditions.

Certain facts peculiar to the locality under consideration led to the adoption of methods almost if not entirely new. There was no material on this ridge that in any way could be used as puddle for a dam, and the bottom and sides of the reservoir were of earth, rotten granite and shattered slate.

To overcome all these difficulties a lining was formed of asphalt concrete, not what is known in the street paving business as asphalt concrete, composed of asphaltum and sand, for clean, sharp sand would have cost $20 per ton to deliver on the mountain, but a true concrete was used of broken stone and asphaltum. The stone was obtained from a porphyry dyke near by, which had been largely broken up by repeated earthquakes, freezing and thawing. This stone was broken into pieces of 2 ins. and under, all the fine material and dust being left in and sufficient fine material added to form, as nearly as it was possible to do so, the theoretically perfect concrete material, where every space between the pieces is filled with smaller

stones even down to fine dust, so that the surfaces of each particle are brought into actual contact with those next to it, and thus only the smallest amount of asphaltum was necessary to bind the whole together in a solid and water-tight mass.

This concrete was prepared in two ordinary pans or kettles from a street paving outfit. The rock was heated and well mixed in one pan, and the asphaltum paste, composed of four parts of California refined asphaltum and one part of crude petroleum, was boiled in another kettle. This boiling hot asphaltum paste was poured with ladles over the hot rock, and the whole well mixed while over the fire with shovels and hoes, until every particle of stone, sand and dust was thoroughly covered with the paste. The concrete was then taken out into hot iron wheelbarrows and put in place in the usual manner, being thoroughly rammed, rolled and ironed or smoothed down with hot irons. This concrete was put on in one layer 4 ins. in thickness, in strips from 4 to 6 ft. in width, and where the strips were joined, the old edge was well coated over with hot paste. After the whole reservoir was lined, it was painted with hot asphaltum paste mixed in the same proportions, but boiled a much longer time, until when entirely cold it was hard and brittle breaking under the hammer like glass, yet tough, elastic and pliable with the least warmth. This painting was done while the paste was very hot and could be ironed down with hot irons. Its thickness should not exceed $\frac{1}{8}$ in.

The results of this work show :

First.—For nearly two years it has stood during two hot summers and one very cold winter without showing a single crack anywhere in the whole structure.

Second.—In one part of the dam, where a trench was cut through it and then filled up, before the lining was put on, the bank settled some 5 or 6 ins. in a strip about 4 ft. wide, and the lining followed the settling, conforming itself to the new conditions without the least break.

Third.—This concrete, formed and applied as here described on slopes of one and one-half to one, has so far shown no tendency to creep, one of the great objections to the ordinary material formerly used, composed of sand and asphaltum.

Before drawing some deductions from the experience derived from this work, it will be proper to record one or two errors, for failures and mistakes are as instructive as successes.

This reservoir lining was put in by contract, and after a large part was completed, the contractor's "practical foreman" concluded that the fine particles and dust used up too much asphaltum. Hence, without the consent or knowledge, and afterwards against the protest, of the author, he sifted out the finer particles, attempting, in his practical economy, to fill these larger spaces with asphaltum, by painting it over with a heavier coating of paste. It is hardly necessary to say this was an entire failure. The paste when hot ran down into these crevices and left fine holes, which of course leaked. To remedy this defect water was turned in with a large amount of sand and earth. This filled the openings and all leaking stopped. The water was drawn off, the surface allowed to dry, and then a second and third coating of paste was applied. While in this case the result was satisfactory for the time being, such work could not be used in a large storage reservoir, or in a more permanent structure.

On the portion repaired in this manner a much too thick painting was put on, and this outside coat, to which some imperfect sand was added, shows the usual tendency to creep or slide, while in no case, even in the imperfect concrete under it, does this creeping show in the least, but the whole of the concrete, after nearly two years, is in as perfect condition and form as the day it was put on. It is proper to state here that this subject of lining reservoirs with asphaltum was first brought before the Society by J. D. Schuyler, M. Am. Soc. C. E., in his paper* on "The Use of Asphaltum for Reservoir Linings."

The so-called concrete which was used in that work was composed of clean sand and asphaltum, the usual composition for street paving. In the discussion† of that paper some important questions were asked, which, as far as known, have not been answered.

Perhaps the experience here related and the following conclusions may somewhat answer those questions.

First.—It is believed that an almost perfect lining for reservoirs, of any size and in any part of the country and any climate, excepting perhaps under the equator, may be had by using an asphalt concrete such as described in this paper, and at a cost much below ordinary methods of constructing water-tight reservoirs. In this instance a lining 4 ins. thick was put on for 15 cents per square foot.

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* See the *Transactions* of the American Society of Civil Engineers, Vol. XXVII, p. 629.
† See the *Transactions* of the American Society of Civil Engineers, Vol. XXVIII, p. 130.

Second.—The concrete should be formed of broken stone (not gravel or sand) in 2-in. cubes and under, with finer particles down to sand and dust, so that every particle will be in contact as perfectly as possible, thus requiring the use of a minimum amount of asphaltum. If this concrete is made in proper proportions and thoroughly mixed, it can be so compressed by hot ramming, rolling and ironing as to be impervious to water throughout its whole mass.

One element of economy, it is believed from some experiments made, comes from the fact that material for such a concrete, not here referring to the asphaltum, can be had cheaply on any reservoir site where rock is at hand. It is not necessary to go to great expense to procure clean sharp sand as is usually specified for hydraulic cement concrete. The finer particles may be composed of even good sandy loam, if clear of roots and vegetable matter, provided the whole mass is properly dried, pulverized, and used in the right proportions.

Third.—The proportions and preparation of what is here called the "asphalt paste" is a very important item. It is to be regretted that the works built were not of such magnitude and importance as to justify extended and careful experiments on this point, and it is hoped that the author or some other member may have the opportunity of making such experiments and reporting them for the benefit of the society. The time required for cooking this mixture to produce a tough, hard, rubber-like material when almost cold and almost as brittle as glass when absolutely cold, cannot be given in exact figures. Of course great care should be taken not to burn the paste while cooking. It is believed that these two facts, the use of a true concrete instead of a porous sand mixture, and a more thorough cooking of the asphaltum paste, will do away with nearly all of the objections to using asphaltum for reservoir linings, especially the creeping of the lining down the banks, and for this reason steeper banks may be used.

Fourth.—One great advantage thus gained is the possibility of forming dams and embankments for reservoirs of material best suited for the purpose of a gravity dam, and entirely eliminating the question of core, puddle or any water-tight method in their formation.

As a basis of cost of the concrete (with such work as is here described, 4 ins. thick, costing 15 cents per square foot), it is estimated that with asphalt at $20 per ton, and working on a large scale, mixing and handling being done by machinery, such concrete can be put in place

and finished 6 ins. in thickness for the same price, 15 cents per square foot, common labor being at $2 per day.

Suggestion for a New Method of Dam Building.—The question has been asked how far one would be justified in following such a mode of construction in large storage reservoirs. The author will state that he has already recommended the building of a storage reservoir in southern California with a dam 120 ft. high on a plan which to him seems to have many advantages in economy, safety and permanence. The recommendation without details is as follows:

After clearing the dam site to bed-rock in the cañon, which is perhaps a quarter of a mile in width at the top level of the proposed dam, with rocky sides and bottom, and preparing proper toe catches in the bed-rock, a gravity dam is to be built of loose rock blasted from the sides of the cañon and dumped in place by cableways.

Care should be taken in placing the larger rocks, which in this way can be handled up to several tons in weight, so as to surround them with smaller pieces, making the mass as compact as possible and reducing the amount of settling and movement to a minimum. This can be done with but very little extra expense beyond a systematic and intelligent dumping of the rock from the grabs and buckets.

The inner face of this dam should be laid up more carefully. A thickness of perhaps 10 or 15 ft. at the bottom and reduced to from 2 to 5 ft. at the extreme top should be placed by hand in the form of a well laid dry wall, on such a slope as, after investigation of details, would be best adapted to the conditions of the special case in hand. The joints of this hand-laid portion should be well filled with spalls, and the surface, considering the direction from side to side across the face of the dam, left as even as can be done without hammer dressing, though not smooth.

Starting from the bottom, as this hand-placed portion is laid up, every 5 or 6 ft. the surface should be stepped back, say, 3 in., leaving a series of 3-in. steps all the way to the top of the dam. On the surface thus prepared, place a true asphalt concrete perhaps 1 ft. in thickness. If the concrete is properly proportioned, well mixed and well laid, with the addition of the 3-in. steps, there will be no difficulty experienced from creeping.

The advantages of the method here recommended are believed to be:

First.—A perfectly safe and permanent dam can be thus built at a minimum cost at the point proposed. With such a lining a perfect joining can be made to the bed rock in the bottom of the cañon and to the side walls from top to bottom. Such a lining would be perfectly water-tight, but in the case of a leak repairs could be made at the smallest possible cost, not only from the nature of the material, but from the fact that the core would be on the outside and thus easily reached. One other source of economy would be the fact that every particle of the material in the dam would exert its full influence in gravity, none of the rock between the usually placed core and the inner surface of the dam being in submersion.

Second.—Such a structure would be permanent from the fact that all the material composing it would be practically indestructible.

Third.—Safety for very many reasons is a most important consideration. Such a structure would be absolutely safe if the dam were properly proportioned. No material in its construction would be affected by the elements, or by animals boring into or through it. In case of possible leaks by cracks from any cause in the asphalt lining, the water coming into the dam proper would be quickly and completely drained away, a very desirable result.

With even a number of cracks formed in the asphalt lining, there would be little or no danger of a great flood caused by the rapid enlarging of the opening, as has been the case in earth and even in cement laid masonry dams. The passing of all the water in a full reservoir through a crack in such an asphalt lining would have very little effect in enlarging the opening. From some personal and severe tests the author has found that such a concrete, with sand and gravel and water passing over it, is practically indestructible as compared with solid granite. The only way a crack would become enlarged would be by the pressure of the water passing through it, but as the pressure would be against the concrete, backed by the solid rock, this effect would be very small. For these reasons it is believed that, considering the results obtained, such a method of construction would be economical, permanent and safe.

The author is aware that there are many places where rock in such quantities could not be obtained cheaply. With his confidence in such an asphalt concrete, as here described, he would not hesitate to use earth and loose rock in the construction of the dam, and in places

where no rock bottom could be found, with perhaps some additional precautions, in placing the lining. But in the great western arid region where storage reservoirs for irrigation purposes are becoming more important and necessary every year, rock is the cheapest material to be had in almost all instances. Throughout this section, both north and south, and also in many parts of the eastern states, the author believes loose rock gravity dams with asphalt concrete lining to be the best and most economical means of securing efficiency, safety and permanence.

The author would make one more suggestion, drawn from his experience in using this asphalt concrete in lining sluiceways. Asphalt concrete is believed to be the best material for lining earth, gravel or shattered rock ditches, sluices, spillways, etc., when high velocities are necessary, and the banks, sides and bottoms must be protected from the action of the water. Especially is it valuable in repairing overflow dams, spillways, etc., since an absolute union can be made with the original structure, of whatever material it may be composed, a result most difficult to accomplish with the best cement, concrete or mortar.

It is hoped that these suggestions may bring from members of the Society and others their experiences in such work, and a full criticism of the methods herein proposed.

DISCUSSION.

P. W. Henry, Assoc. M. Am. Soc. C. E.—Asphalt blocks such as are used for paving are made with a concrete similar to that described in the paper. The rock is crushed and all the broken stone, ranging in size from 1 in. to an impalpable powder, is used. The results vary according to the kind of rock used; with soft limestone the blocks have not been so satisfactory as with trap and granite, which are now employed exclusively. Mr. Henry.

Experiments have been made with asphalt paving mixtures, using Portland cement and Rosendale cement in place of the ordinary stone dust, but it is uncertain whether there is any advantage in such a practice.

Edward P. North, M. Am. Soc. C. E.—There is no statement in the paper as to the proportion of asphalt or bitumen used in the concrete. The author stated that the finer particles may be composed of good sandy loam, but the speaker believed that whenever there is any clay in combination with asphalt, it tends to produce disintegration. In asphalt pavements it is rather necessary that pure sand should be used with Trinidad bitumen; California bitumen is purer and may stand a larger proportion of clay without injury. He considered that there is ultimate danger in using any clay in combination with bitumen intended to resist weather or wear. Mr. North.

With regard to the use of maltha, it has been found in Europe, where asphalt proper, an amorphous limestone naturally impregnated with bitumen, is employed in contradistinction to bitumen as in this country, that the best results are obtained with *goudron*, which is very like the California maltha. The best *goudron* came from sandstone rocks in the Pyrenees, but this source of supply is now exhausted, and shale oil, or Strasburg grease as it is sometimes called, is used instead. This is a rock bitumen which flows like molasses and was said in Europe to produce a better asphalt than that made with still bottoms. He did not know until recently that the California bitumen with maltha had been used practically and commercially in this country for paving streets.

Boiling the asphalt to drive off the lighter oils, while it will undoubtedly produce a harder product, may not be as good a line of experiment as adding lime dust. Whether the asphalt will deform or not depends upon its temperature; if cold enough, even the softest kinds will hold their position. Experiments made by the speaker some years ago showed him, so far as they went, that the addition of lime dust, or, perhaps better, hydraulic cement, would keep any mixture of asphalt or bitumen from losing its shape more successfully than by driving off the lighter oils.

Mr. Whinery. SAMUEL WHINERY, M. Am. Soc. C. E.—The speaker thought that there might be a danger in rock-fill dams of the loose rock settling away from the asphalt lining when the latter was very brittle, thus breaking the water-tight coating and possibly leading to serious leaks. A large number of tests of asphaltic mixtures made under his direction indicate that had the author mixed with the asphalt from 10 to 15% of very finely pulverized limestone or clay, the strength of the concrete would have been increased and its brittleness greatly decreased. When asphalt pavements were first begun in this country, experiments were made with a number of asphalts, one of the earliest being a nearly pure Cuban bitumen. It was found in practice to make a very brittle pavement, so brittle that it soon disintegrated under the horses' feet. Further trials showed that the Trinidad asphalt is very well suited for that purpose, its superiority being doubtless due to some extent to the fact that it contains a large percentage of very fine silicious and aluminous matter, which is found very intimately mixed with the bitumen. It has been shown by laboratory experiments that Cuban, Bermudez and Californian asphalts in their pure states are exceedingly brittle, but by mixing with them 10 to 15% of powdered limestone, the brittleness and the tendency to flow or creep on account of changes in temperature are decreased.

The preparation of concrete with bituminous cements is not new, and the same principles apply to it as to the making of hydraulic cement concrete. The author is right in saying that it is desirable to have the mass as nearly solid rock as possible. The fragments of rock should be of different sizes so that the smaller will drop into the voids between the larger, reducing the interstitial space as much as possible, and consequently the amount of asphaltum cement required. Concrete of this character has been made for street foundations for a number of years and has been found entirely successful, although for that purpose not so large a proportion of bitumen is used as would be necessary were it desired to make it water-tight. The speaker regarded its expense as a serious matter in reservoir construction. While the cost of this lining, 15 cents a square foot, seems comparatively small, it amounts to over $12 a cubic yard. Unless ordinary puddling were very difficult and expensive to obtain, it is a question whether an equally good and tight dam could not be made with a clay puddling at a less cost. In the case mentioned in the paper it seemed that the material for making a water-tight lining on the inside of the dam was absolutely unobtainable, and doubtless the construction was the best which could be adopted under the circumstances.

With regard to the use of maltha in place of petroleum as a flux for bitumen, there is a popular but erroneous idea held by many people interested in the sale and use of asphalts that California maltha, which is a thin asphalt of about the consistency of tar, is a much better ma-

terial with which to temper and soften bitumen than petroleum. The theory is that since asphalt is composed of two substances, petroline, which is readily made fluid, and asphaltine, which is practically brittle and is not soluble in certain solvents, the maltha acts as a solvent for the asphaltine and converts it into a cement equal in all respects to the petroline. Careful experiments in the laboratory will show this to be entirely incorrect. Asphaltine is as absolutely insoluble in maltha as it is in water, and for that matter it is insoluble in the residue of petroleum stills. Mr. Whinery.

ROBERT CARTWRIGHT, M. Am. Soc. C. E.—The speaker had seen 30-in. riveted pipe in California, which was put together like stove pipe, and, although no rivets were used at the joints, it held together, even when curves were turned. One of these pipes was in service under a head of about 1 000 ft. The sheets were $\frac{1}{16}$ in. thick at the upper end, and gradually increased in thickness to $\frac{3}{8}$ in. at the bottom. In laying such pipes one end of a section is flared a little by hammering so as to form a socket, and the end that is to be inserted in it is drawn a little so as just to enter the socket. The lengths are dipped in a bath of asphaltum at the shop. In jointing the lengths together a swab dipped in petroleum or maltha is wrapped around the socket and then fired. The heat expands the metal, the male end of the next pipe is then inserted in the socket, and the pipe is driven home with a maul or battering ram. The same method is followed in turning curves. The jointing is done so that the longitudinal seam where the plate laps over on the outside section is flush against the seam on the inside section. Such pipes are laid with the male end up stream, and to prevent leakage earth is dumped into the water that passes through the main first. This earth collects in the seams and joints, and is forced into them by the pressure of the water, eventually preventing all leakage. Mr. Cartwright

There is rarely any provision for expansion and contraction in these pipes, as the divergencies from a straight line furnish a means of compensating for such changes in length. The speaker had found in his own practice that the expansion and contraction of wrought-iron pipes 7 ft. in diameter and 200 ft. long was amply provided for if there was an elbow somewhere in the length. At Rochester, for example, he constructed a 7-ft. pipe to carry water under a head of 93½ ft.; in spite of the fact that it is cooled in winter to the temperature of anchor ice, no leakage occurs, owing to an elbow that takes up the expansion and contraction.

H. D. BUSH, M. Am. Soc. C. E.—During the years 1893 and 1894, while the speaker was employed in the construction of the Bull Run pipe line now bringing water into the city of Portland, Ore., four reservoirs, one high service and one low service for each side of the Willamette River, were also under construction, principally in excavation. Three of them were lined with concrete and one with brick laid Mr. Bush.

Mr. Bush. in asphalt, all lining being afterward covered by several coats of asphalt. Reservoirs Nos. 3 and 4, on the west side of the river, were built in a ravine, the hills on one side of this ravine being high and the ground full of springs. Some movement of the ground in Reservoir No. 3 took place during construction, and a large block of concrete was placed in the bottom of the reservoir to act by its weight in holding the bottom of the slope in position.

When the reservoirs had been used but a short time, leaks were discovered in No. 3, due to the cracking of the concrete lining, which allowed the water to escape through the ground around one end of the dam. Tunnels were then driven into the hill on a level with the bottom of the reservoir and drain pipes put in. The following extracts from letters on the subject from Isaac W. Smith, M. Am. Soc. C. E., chief engineer of the Portland Water-Works, and D. D. Clarke, M. Am. Soc. C. E., principal assistant engineer, were presented:

"On the west sides of Reservoirs 3 and 4, the soil back of the slopes was saturated with water from springs, and the crack along *A B* (see Fig. 1) was caused by an inward horizontal movement of the surface slopes, together with the pressure of the berm and parapet wall. I send you a memorandum from Mr. Clarke in relation to the asphalt coating. The asphalt runs when too soft, and cracks with the concrete when hard. Small 'checks' in the concrete are filled with asphalt by the pressure of water, but the asphalt breaks and is forced through when there is a crack through the concrete from settlement or other cause. As the asphalt does not prevent leakage through cracks in the concrete and the concrete always cracks on the slopes and bottom of reservoirs, I think it would be best to place the asphalt under the concrete when the soil is solid and clay for puddling cannot be obtained. "ISAAC W. SMITH."

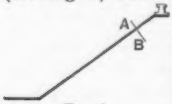


FIG. 1.

"The first coat was of F grade Alcatraz asphalt, put on with brushes or mops while hot. This coat was about $\frac{1}{16}$ in. thick. After being put on, it was smoothed with hot irons, which reduced its thickness somewhat. It was then sprinkled with hot sand.

"The second coat was usually of XXX asphalt, but XXXX grade was used on a portion of one reservoir. This coat was applied hot and was from $\frac{1}{8}$ to $\frac{1}{4}$ in. thick, being somewhat thicker on the bottom than on the slopes, and was not ironed, the thickness of the two coats ranging from $\frac{3}{16}$ to $\frac{5}{16}$ in.

"Some of the reservoirs were not filled at once after the asphalt coating was applied, and with the first warm days that followed the asphalt lining began to creep or wrinkle. This continued until the entire surface exposed to the direct rays of the sun assumed a rough or wavy appearance.

"Later in the season, June 11th and 26th, 1895, tests were made at Reservoirs Nos. 1 and 2 which showed that the asphalt coating would soften and begin to creep when the thermometer indicated 90° at one point and 82° at another. Readings were taken in the sun on the face of the slope.

"On the slopes of all the reservoirs, except No. 1, which was kept filled with water, the asphalt wrinkled badly, numerous places 1 sq. ft.

in area, and over, being almost entirely bare of all asphalt excepting part of the first coat, which had been ironed on. **Mr. Bush.**

"The work done on Reservoir No. 3 during August and September of this year, 1895, consisted of a single coat of XXX asphalt. On the slopes it was applied about $\frac{1}{16}$ in. thick and $\frac{1}{8}$ in. on the bottom. That used on the slopes was made considerably harder than the coating applied on the bottom. In a few places two coats were applied. So far as observed this work has shown no signs of wrinkling, but the single coat did not prove to be sufficient to protect some small cracks which have since appeared in the concrete lining. These cracks were small, but a second coat of asphalt should have been applied in order to properly cover them. "D. D. Clarke."

It seemed to the speaker that the asphalt coating as first put on was too thick as well as too soft, while from exposure to the sun during an Oregon winter the asphalt ran down the slopes of the reservoir in wrinkles or folds.

Rudolph Hering, M. Am. Soc. C. E.—In the use of asphalt at Babylon and Nineveh, about 4 000 years ago, it was employed as a mortar, and was also mixed with broken bricks and stones to form a concrete, in a manner somewhat similar to that described in the paper. Asphalt was used in Egypt, particularly in Memphis, for keeping moisture out of walls and basements. In a German pamphlet published in the early part of the seventeenth century, mention is made of the application of this material for various industrial purposes, and in 1692 large quantities of bituminous rock were discovered in the Val de Travers, in the canton of Neufchatel, Switzerland. The first practical use made of asphalt in modern times, however, was by a Greek physician, Dr. Eyrinis, who had been requested to make a geological examination of parts of Switzerland and rediscovered the Val de Travers beds. He also found the beds at Lobsann, in Alsace. He experimented with the material, and recommended its use chiefly where its water-tight qualities might be utilized. There are records of cisterns 16 to 20 ft. in diameter, which were laid in asphalt and retained water quite successfully. Count Buffon, the French naturalist, recommended asphalt to be used as a mortar in building a large basin in the Jardin des Plantes in Paris, and some 40 years later he wrote that it had remained perfectly water-tight. **Mr. Hering.**

The Val de Travers mines were again neglected, as it seemed impossible to accomplish as much with the material as had been expected. In 1802 the Seyssel mines were discovered, and there the rock was richer in bitumen. They were not worked extensively until after 1832, when Count Sassenet took hold of them, and it might be said that the modern practical utilization of asphalt began with his efforts. He found that the natural rock could be improved by mixing with it a natural bitumen or maltha, of which deposits were found in the vicinity. The asphalt mastic made in this way has since then been used extensively for sidewalks in France.

Mr. Hering. An engineer named Merian, located at the Val de Travers, noticed in 1849 that the pieces of rock which fell from the carts into the ruts were compressed and formed a substantial roadway. This is said to have been the origin of the use of rock asphalt for paving, and when the speaker visited the mines a few years ago, this old roadway was shown to him. Mr. Malo developed the Seyssel mines more fully, and, with Mr. Delano, published the best information of the time about the industry, especially with regard to road-making.

In 1843, asphalt mines were discovered at Limmer and Vorwohle, near Hanover, Germany, by a Mr. Henning, who studied the applications of asphalt and wrote, as the speaker believed, the first treatise on the practical use of asphalt for industrial purposes. The German asphalt contained 17% of pure bitumen at that time, while the Val de Travers and Seyssel asphalt contained only 8 to 12 per cent. Mr. Henning recommended employing asphalt to make cisterns water-tight, and advised placing it as a filling between two masonry walls. He stated that it is an excellent material with which to cover inclined surfaces and protect them from the penetration of water, and, if but one coating is put on, he recommended using some textile fabric of hemp or linen as a foundation to keep the asphalt from crawling, omitting the fabric if two coats are employed. He stated further that sand should always be rubbed on the asphalt surfaces, not only to increase the stiffness of the material, but also to give it a lighter color, which reduces the absorption of heat and consequently the flowing or crawling of the asphalt. He even recommended a coat of whitewash to prevent this creeping.

Mr. Henning also stated that the best asphalt will lose its oily substance in time, and recommended that the surfaces should be painted with hot maltha every eight to ten years. He wrote that vertical walls can be coated with asphalt to protect them against moisture, and said that this should be used in the form of pure mastic or bitumen, without any sand. For application to reservoirs, he preferred two thin coats of maltha to a thicker one.

Subsequently there came into general notice the Trinidad asphalt, which has a comparatively high percentage of bitumen, then the Bermudez asphalt, and finally the Alcatraz asphalt. The Bermudez asphalt is said to be richer and to retain its volatile oils longer than that from Trinidad. The Alcatraz mines are located near Santa Barbara, Cal. From one of them, Las Conchas, a very high grade of bitumen mixed with fine sea sand is obtained, while at another mine, La Patera, a rock asphalt is found. For practical purposes in California, a mixture of the two has generally been used.

In a paper* presented to the Institution of Civil Engineers, Mr.

* "The Use of Asphalt in Irrigation Works in California," *Proceedings* of the Institution of Civil Engineers, Vol. CX, p. 286.

FIG. 1.

FIG. 2.

Gervaise Purcell recommended a reservoir lining of three parts of gravel Mr. Hering. and one part of sand, to which 10% of asphalt mastic has been added. He heated the gravel and sand in a horizontal cylinder to a temperature of 310° Fahr., added the asphalt at a slightly lower temperature, and then turned the whole mass over so that the materials were thoroughly mixed. The mixture was tamped against the slope and not rolled, because the rolling was said not to compress the material sufficiently to remove all the interstices. The speaker preferred the use of crushed rock to gravel, as the concrete prepared with it would be less likely to move down the slope.

At Portland, Ore., he had examined three reservoirs having thin coats of asphalt on their slopes, and one reservoir on which the slopes were paved with two courses of brick dipped in asphalt. The asphalt coatings had slipped and crawled on the slopes, as shown in Plate I, Fig. 1, but in no case had they entirely left the surface of Portland cement concrete upon which they had been placed. The asphalt was applied in two coats, and it was intended to make the second a little harder than the first; but on account of bad weather this had not been done, and the crawling is attributed principally to this fact. In order to make the asphalt adhere to the concrete, it was found necessary to apply the first coat very soft, mixed in the proportion of one part of asphalt to two and a half or three parts of gasolene, and recent experiments at Philadelphia confirmed this practice. The speaker exhibited a specimen of asphalt lining which had adhered so strongly to the concrete that it had pulled off the cement surface when removed.

The asphalt lining of the Denver reservoirs* was stated to have been unsuccessful. The material was softer than when first laid, and had shrunk and cracked seriously where not exposed to the water. Much of it had crawled down the slope, as shown in Plate I, Fig. 2, even when under water. It was said that if there was any difference at all in the condition of the linings, that made with Alcatraz asphalt was superior to that made of Trinidad asphalt. The speaker's observations and inquiries led him to believe that the best method of applying asphalt for reservoir linings was either to have upon a concrete surface, the thinnest practicable coat of asphalt, free from sand, or to use an asphalt concrete, as described in the paper.

JOHN C. TRAUTWINE, Jr., Assoc. Am. Soc. C. E.—Asphalt was used Mr. Trautwine. in making repairs to the Queen Lane Reservoir of the Philadelphia Water-Works, which leaked so badly when partly full that it had never been filled entirely. The reservoir consists of a north and a south basin, partly in excavation and partly in embankment, the bottom of the basins being at an elevation of 208.33 ft. above the city datum, and the intended elevation of the water surface 238.33 ft. The bottom and slopes of the reservoir are lined with 2 ft. of somewhat micaceous

* See the *Transactions* of the American Society of Civil Engineers, Vol. XXVII, p. 629.

a layer of brick laid flat and dipped in asphalt, with proper precautions, or

Mr. Trautwine. clay, obtained in the neighborhood, which was well rammed, and ought to have held water when the reservoir was filled to the moderate depth of 10 ft., to which it was subjected before the repairs were begun. The clay on the sides is covered with concrete slabs 10 ft. wide, 12 ins. thick at the bottom, 6 ins. thick at the top, and running from the top to the foot of the slope. The first slabs were laid with 10-ft. spaces, which were afterward filled with similar slabs, and it seemed to the speaker that the cement used for the surface finish must have varied in quality, as the slopes appear under certain atmospheric conditions to have alternate light and dark bands. The clay on the bottom is overlaid by a concrete floor 4 ins. thick, the edges of which overlap the foot of the slope.

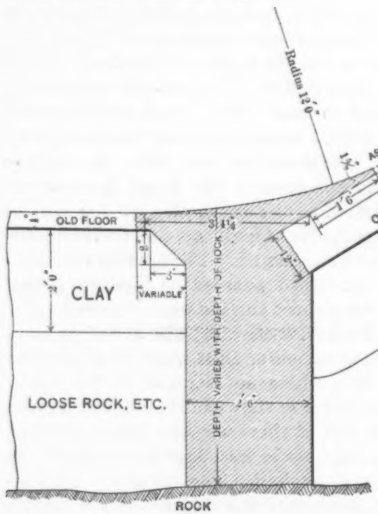


FIG. 2.

The concrete slabs on the slopes cracked across in nearly continuous lines at heights of about 5 and 10 ft. above the bottom, except on a portion of the slope which formed a reversed curve. Before the repairs were made, the rain that fell on the surface of this concrete was fed by the horizontal cracks into the longitudinal joints between the slabs, and passed through these to the clay below. The clay was softened and washed away to some extent, especially near the foot of the slopes. Many of the slabs which were thus left unsupported at the lower portion of their length yielded somewhat under the weight of 10 ft. of water over them, and their lower edges were pressed down so as to leave a space between them and the concrete floor, amounting

in some cases to 1 in. Through this space the water was seen escaping freely, even when its depth was such as barely to cover the space. In some cases the rain water passed down the slope between the concrete and clay, carrying portions of the latter with it, and came up between the slopes and the floor, leaving small mounds of clay within the reservoir. Mr. Trautwine.

The repairs were made by constructing a concrete wall under the foot of the slope of one basin, and by closing the horizontal cracks and seams and the joints of the concrete on the slopes with melted asphalt, which was also used in closing the joints and larger cracks in the floor.

The design of the footing wall is shown in Fig. 2. It is 2 ft. 6 ins. wide, and runs down to a firm foundation on the underlying stratum of micaceous rock, which becomes more or less decomposed as it nears the surface. The wall is about 3 600 ft. long, and extends entirely around the basin. The floor was originally almost level, its inclination being just sufficient to insure drainage. In the new construction, it was finished with a curve tangent to the floor and the slopes, the curved surface being finished with a 1-in. coat composed of equal parts of sand and cement. The small triangle above the concrete was filled with a mixture of sand and asphalt. In building the wall every effort was made to afford a support to the foot of the slope, and this work was made easier by heavy rains which fell while the trench was open. These undercut the concrete slabs to some extent, and it was necessary to ram the concrete with an improvized wooden tool, shaped somewhat like an adze and struck with a sledge while held against the concrete placed under the toe of the slope.

The asphalt repairs were made on both basins. The material used was composed of four parts of Bermudez asphalt and one part of the liquid or F grade of Alcatraz asphalt. These were melted together and poured on the surface to be treated, which had been previously primed with a thin coating consisting of three parts of the F grade of Alcatraz asphalt and seven parts of gasolene. The asphalt was only partly liquid, and it was necessary to melt it before it could be dissolved in the gasolene.

The priming coat was allowed to dry thoroughly before the asphalt was applied over it, in order that all the gasolene might escape. The use of this priming coat was found to be of the utmost importance. Asphalt placed on it adheres quite tenaciously, while if applied directly to the original surface of the cement concrete, it breaks off readily.

The horizontal cracks in the concrete slabs on the slopes and the seams between the slabs were given a single coat of the melted asphalt. At the outset, the seams were given two coats of asphalt with a strip of burlap between them, but this plan was abandoned on account of

Mr. Trautwine. the time required to carry it out. It was also found that the burlap, not being anchored at the top, had a tendency to creep down the slopes and to buckle near the foot. In the basin where the footing wall was not used, the melted asphalt was applied over a width of about 1 ft. on the slope and on the floor, extending each way from the joint between them, and special pains were taken to secure a considerable thickness of the asphalt at the joint itself. In the second basin, the entire surface of the new concrete footing wall and of the triangle of asphalt and sand about it was covered with the melted asphalt, which was made to cover all the joints of the new surface. Two or three large cracks in the concrete floor of each basin were filled carefully with asphalt mixture. As it was necessary to have the cracks and seams in the slopes closed before winter set in, the work was hurried and carried on at times in weather which it was feared might prove later to have been too damp. Two methods were accordingly adopted to dry the concrete locally. The first was the use of gasolene hand torches, and the second was the use of gasoline stoves, such as are used for softening asphalt pavements in repairing streets. This type of stove consists of a sheet iron shield or reflector placed a few inches above the concrete and having below it a number of gasolene jets or burners.

Before the repairs were begun, the reservoir lost water from all causes at the rate of about 0.4 in. a day from one basin, and 0.9 in. from the other, under a head of 5 ft., while since the repairs, the total loss under the same head amounts to from 0.1 to 0.25 in.

CORRESPONDENCE.

Mr. Le Conte. L. J. Le Conte, M. Am. Soc. C. E.—Asphalt lining for new reservoirs and for repairing old leaky ones has been in use for many years in California and adjoining States. The results obtained so far are most encouraging. For the bottom and side-slopes flatter than 1½ to 1, the best mixture is either asphalt mortar or asphalt concrete. It is the cheapest and best lining, and there is no danger of it crawling down the slopes. For steeper slopes up to vertical faces, this kind of lining has been tried and found wanting in many respects. Under a hot summer sum it will creep down the faces in spite of all precautions.

Steep slopes or vertical walls are now coated as follows: *First*, with a cold liquid asphalt paint which has great penetrating and adhesive properties, but is lacking in sun-proof qualities; *second*, with a heavy layer of ordinary burlap, which is tightly stretched and pressed into this liquid asphalt paint; *third*, with a heavy outside coat of hard asphalt

See errata p. VI,

Mr. Le Conte.

paint, put on boiling hot. This constitutes the weather coat, and is hard, tough and resists the hot summer sun admirably. Wherever this lining has been used, no signs of creeping have developed, even on smooth vertical faces. Hard asphalt paint is lacking in adhesive qualities, and consequently cannot be placed directly on the slopes. The contract price for this lining has varied from 12 to 16 cents per square foot, depending upon local conditions.

Dry-stone dams have been in use in California for storage purposes, in mining districts, during the past 30 to 35 years. A sketch of the characteristic section is shown in Fig. 3. These dams require about three times the cubical quantity of stone which would be called for in a properly designed masonry dam, but the first cost, \$2 to \$3 a cubic yard in place, is so low that in many places they have performed a

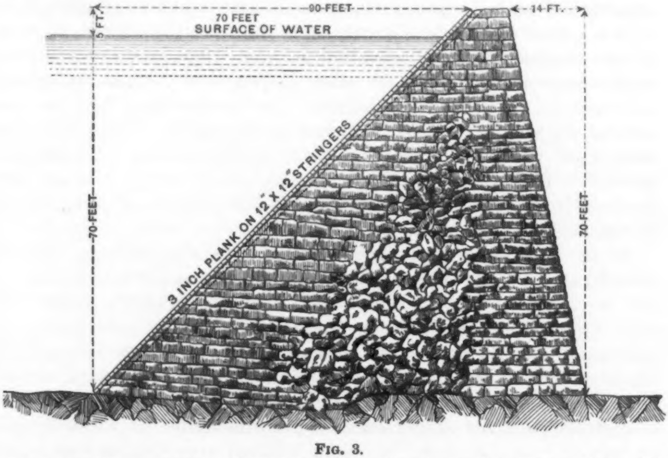


Fig. 3.

most useful purpose. These dams are lined on the water side with 3-in. plank, sometimes with two thicknesses. The foundation in all cases is solid rock free from fissures.

While it is proper to give these dams full credit for all past and present usefulness, yet it is hardly right to call them perfectly safe and permanent. Past experience shows clearly that whenever a serious leak develops, or should the dam be overtopped by flood waters, the dry-stone structure will be literally blown away, like chaff before the wind. After the failure of the English dam on Yuba River, in California, in June, 1883, not a vestige of stone was found for a distance of 1 500 ft. below the site of the dam, and all large stones used in construction, each weighing several tons, had disappeared entirely; probably they were ground into smaller fragments.*

* See the *Transactions* of the Technical Society of the Pacific Coast, Vol. II, p. 3.

Mr. Le Conte. The author's suggestion of substituting asphalt concrete in place of the wooden planking as a water-tight lining for the up-stream face of the dam seems to be reasonable, but experience alone can determine whether it is better construction. This type of dam is eminently suitable for large storage reservoirs in remote districts where civilization is not likely to encroach upon the valley below the site. They are cheap, practical and within certain limits reasonably safe, but like earth dams they require constant supervision and quick attention.

Mr. Davis. A. P. Davis, Assoc. M. Am. Soc. C. E.—In 1894 the writer was associated in the formulation of plans for a large irrigation system in California, in which canal velocities of from 8 to 12 ft. per second were required, and it was decided to line the canals with concrete, composed of sand, broken stone, and sufficient asphalt of high grade to form a good bond. It is gratifying to find that the author's experience so emphatically vindicates that decision. The side slopes of the canal were to be 1 to 1. In the same project were included the plans for a rock-fill dam 120 ft. in height. The construction here recommended was similar to that described in the paper, except that the water-tight face of the dam was to be a double floor of redwood, fastened to timbers built in the rock and properly calked. An asphalt concrete facing was carefully considered, but reluctantly abandoned, for the following reasons:

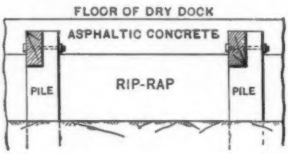
In the absence of satisfactory evidence to the contrary, it was thought that a sheet of asphalt concrete of such magnitude would be sure to creep sufficiently to impair its efficiency seriously, unless the slope were made so much flatter than demanded for a timber face as to enhance greatly the cost of the rockwork, and, even then, the cost of repairs, owing to the difficulty of access to the site of the dam, would be so great as to render new experiments rather hazardous. It is to be regretted that the author omits to state the slope on which he expected his "outside core" to stand without creeping, and on what experiments he based his expectation. It would seem that his recommendation of 1 ft. thickness is excessive, and tends to increase the danger of creeping, by removing a part of the load a greater distance from its bond with the rough rock face.

This is an important question in the arid southwest, and further light on the subject is badly needed, especially as to the greatest slope at which it is possible to place this concrete safely without impairing its adaptability to the settlement of its backing. As to the exact composition of the concrete, and the time and method of cooking, it would seem to be necessary to make experiments for each individual structure, and even for each consignment of asphalt, as the composition and physical properties of even the best asphalts vary somewhat.

ROBERT A. CUMMINGS, Assoc. M. Am. Soc. C. E.—In preparing the design for the floor of a large dry dock, where a strong and impervious but inexpensive construction was required, the writer contemplated using an asphaltic concrete floor as shown in Fig. 4. No data was at hand concerning the strength of such a concrete to resist the hydrostatic pressure, or how it would act as a monolith under temperature stress, or what its length of service would be when alternately wet and dry. It was assumed that the flexibility of an asphaltic concrete was greater than that of cement concrete, and that this would render it less liable to crack where it was attached to the piles and timber framing. It also appeared to have other recommendations suggesting its suitability for a dry-dock floor. Mr. Cummings.

The design, however, was modified as shown in Fig. 5. In this case relief from hydrostatic pressure is partly obtained by drainage through the rip-rap and broken stone foundation of the floor.

The tops of the piles and timber framing are flush with the top of the broken stone. Over the top of the broken stone, piles, and timber



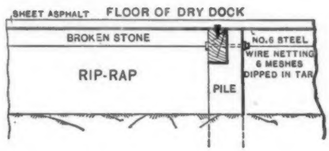


FIG. 4. FIG. 5.

framing, is laid a No. 6 steel wire netting with 6-in. meshes. This netting has been previously dipped in boiled coal tar. It is then securely fastened by staples to the piles and timber framing. The netting is introduced to add strength and to act as a binder to the asphalt finishing course above.

The specifications of the asphalt finishing course are the same as are used for ordinary street paving. The writer believes that this floor admits of being modified to suit the lining of reservoirs. He desires to ask what is the effect of sea water and brackish water upon asphaltic compositions. He also inquires what is the condition of asphalt linings at the water line in reservoirs after two or three years' service, also what is their durability.

ROBERT BREWSTER STANTON, M. Am. Soc. C. E.—Before considering some of the points brought out in the discussion of his paper, the author desires to state that it was not his intention to claim as original or even new either a rock-fill dam or an asphalt lining for reservoirs; but if there was anything really new in his suggestions it was the combination of the several items for storage reservoir dams, and especi- Mr. Stanton.

Mr. Stanton. ally the use of a true asphalt concrete, which it was believed had never before been used for such purposes. It is certainly of advantage to have drawn out some information from the experience of other engineers and such historical facts as given by Mr. Hering. It is to be regretted, however, that others have not given facts and data in their possession for the benefit of the Society.

A number of members and others during the past few years have made extensive and valuable experiments in the use of asphalt (especially in the amount and proportion necessary for a perfect mixture) and also in the construction of modern rock-fill dams. The author personally requested several of them to give their data and experience in the discussion of this paper, and regrets exceedingly they have not been able to do so.

Mr. Hering's historical facts are both interesting and instructive, It is very gratifying to learn that the large basin in the Jardin des Plantes in Paris, built with asphalt, "had remained perfectly water-tight for 40 years," and, if the opinion quoted from Mr. Henning be correct, that the best asphalt will lose its oily substance in time, and should be painted with hot maltha every 8 or 10 years, it is a strong argument for the outside core suggested in the paper.

One of the most remarkable uses of asphalt for the core of a dam is in the work described by Mr. Skinner, in the discussion of Mr. Van Buren's paper on "High Masonry Dams."* The author very recently visited and carefully examined the dam there referred to, then being built in Southern California. It is not the intention to discuss that work, except so far as the asphalt used forms the entire effective core of the dam, and shows most questionable engineering practice. As described by Mr. Skinner, this dam is a loose rock-fill dam, and when completed will be 130 ft. in height. In the center of this is placed a core "of thin riveted steel plates from No. 0 to No. 3 Birmingham gauge. As each course of plates is calked and completed it is coated with a special preparation of asphalt (pure, soft Alcatraz asphalt). Burlap is then placed over the top edge and on each side of the steel, and a coat of (pure, hard Alcatraz) asphalt put over it, making two coats on each side of the plates. On each side of the web built up in this manner is a 24-in. (to a 12-in.) hydraulic cement concrete wall," with the rock-fill dam built against it. This is called a steel core, but looking at this dam as a permanent structure (and it certainly should be permanent, built as it is at the head of a large agricultural valley, and for the purpose of supplying water to a future large city) it is, more properly speaking, an asphalt core, for the following reasons :

The concrete walls on either side of the steel can in no way be depended upon as part of a water-tight core, subject as they are to the strains from the settling of such a rock-fill dam, and being in an earth-

* See the *Transactions* of the American Society Civil Engineers, Vol. XXXIV, p. 506.

quake country. This concrete is placed in the manner and position where it is, simply to protect the asphalt from injury by the filling in and settling of the rock against it. The steel itself, with the water in contact with it (without the asphalt), would have but a limited life, especially in consideration of the nature of the soil and water in Southern California, from 7 to 10 years at the most. Hence, as a permanent structure, the water-tight core of this dam consists of a sheet of asphalt and burlap, say ¼ in. in thickness, standing vertically in the center of a rock-fill dam, this sheet of asphalt being supported in place by steel plates. Mr. Stanton.

The engineering defects of constructing an asphalt core in this manner are:

First.—The entire want of certainty in the permanence (beyond a few years) of such a thin sheet of asphalt in a vertical position in a loose rock-fill dam.

Second.—The placing of such a core, both steel and asphalt, where, financially speaking, it is beyond the possibility of being repaired.

Third.—The absurdly excessive first cost of such a core, which cost, to the present time, has been more than five times what it would have been to put on an asphalt concrete face, such as suggested in the paper. It is gratifying to state that the engineer in charge of this work is not responsible for the defects of plan or the great cost of the work. This belongs to the president of the company, but in the execution of the details, the engineer has shown marked ability and a conscientious painstaking which cannot be too highly praised.

There are three points in the discussion that seem to require notice.

First.—The nature and proportions of the concrete used. The author regrets, as stated in the paper, that he cannot give more detailed data. From some statements made by members of the Society in this discussion, he is more than convinced that the profession is in need of careful experiments and well kept data upon this subject. The following quotations illustrate this point.

Mr. North "believed that whenever there is any clay in combination with asphalt it tends to produce disintegration."

Mr. Whinery says "that had the author mixed with the asphalt 10 to 15% of pulverized limestone or clay, the strength of the concrete would have been increased."

Mr. North says "that the addition of lime dust or, perhaps better, hydraulic cement would keep any mixture of asphalt or bitumen from losing its shape," etc.

Mr. Henry says that from experiments made, "it is uncertain whether there is any advantage in such a practice," that is, in adding cement.

The author does not presume to decide between such authorities, but does express the hope that much more definite and reliable data

Mr. Stanton. from actual work or experiments will be given the Society, and as a contribution toward this he submits his work with a test of two and a half years.

Second.—Permanence. Mr. Le Conte thinks the author claims too much for the permanence of the methods suggested. What he says as to the power of water in washing away great bowlders of several tons' weight is of course correct.

The possibility of such a contingency as the stream overflowing a rock-fill dam is not to be considered. Means to prevent this positively should be one of the first provisions in the plan. The construction of an earth dam like that across the Pecos River above Eddy, New Mexico, which the author visited last summer, where a lake is formed covering 8 331 acres, and containing 45 000 000 000 galls. of water, would be worse than a mistake, it would be a crime, except for the waste ways provided above the dam, with an aggregate cross-section area ten times that of the dam and 10 ft. below its crest.

The following facts may throw some light upon the permanence of asphalt concrete. In connecting the bed-rock cut with the sluice of the hydraulic mine, described in the paper, the space *A* (Fig. 6),

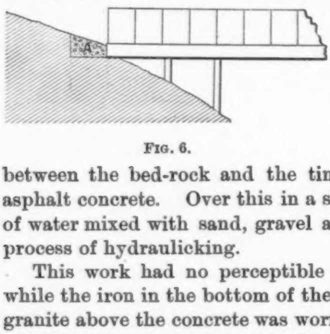


FIG. 6.

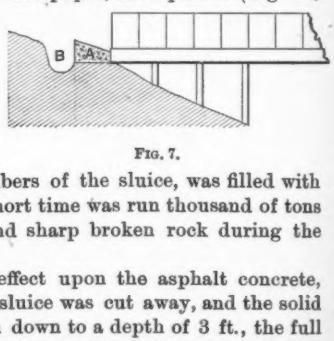


FIG. 7.

between the bed-rock and the timbers of the sluice, was filled with asphalt concrete. Over this in a short time was run thousand of tons of water mixed with sand, gravel and sharp broken rock during the process of hydraulicking.

This work had no perceptible effect upon the asphalt concrete, while the iron in the bottom of the sluice was cut away, and the solid granite above the concrete was worn down to a depth of 3 ft., the full width of the cut as shown at *B* in Fig. 7. Hence it is claimed that through a crack or a hole as large as the wrist, the amount of water in any reservoir, even with sand or gravel, might pass without any enlargement of the crack or hole in the asphalt, or any danger to the dam itself.

The thickness of 1 ft. of concrete was suggested to provide ample material to fill up the unevenness of the rock slope, and the 3-in. offsets. From 4 to 6 ins. of asphalt concrete is entirely sufficient as a water-tight material, but it is believed that a thicker coating would cost less than the amount necessary to form a smooth surface of rock or cement concrete to place the asphalt upon, and a broken stone asphalt concrete properly formed and applied will not creep.

Third.—Definite figures have been asked for as to cost of rock-fill dams. The prices given by Mr. Le Conte of $2 to $3 per cubic yard must have been of those dams built 30 to 35 years ago to which he refers. The following figures are of a recently constructed dam in Southern California where modern machinery and powder were used to do the work, and are correct and reliable. Mr. Stanton.

Data.—Common labor cost $1 75 per day. Coal cost $10 per ton. The plant consisted of one Lidgerwood cableway with three derricks on the dam for distributing and placing rock. Quarrying was done by exploding several tons of powder in drifts and shafts, thus breaking up from 25 000 to 30 000 cu. yds. of rock by one shot. The total amount of rock in the dam was about 120 000 cu. yds. The first cost of the plant was $12 000 in round figures. The cost of the rock in place was as follows :

Quarrying rock....................	6	cents	per cubic yard.
Loading buckets (by hand), including breaking larger rock with powder.........................	20	"	"
Hoisting and conveying rock......	6	"	"
Placing rock on dam..............	3	"	"
Cost of plant.....................	10	"	"
Total......................	45	"	"

This includes all repairs, and the total destruction of the whole plant in this one piece of work.

There are local conditions at this particular point where, if proper forethought had been used, this price could have been reduced at least 5 cents per cubic yard, and whatever value there may be at the conclusion of the work in the cableway, the boilers, engines, etc., would still further reduce the cost per cubic yard. The engineer who has so successfully carried on this work, under some very trying conditions, deserves the greatest praise for the skill, thoroughness and economy with which he has executed it.

The author is aware that there are places where rock-fill dams might be advisable, where these figures would be far too low, and yet he is also acquainted with valuable reservoir sites where rock-fill dams can be built (not including preparation of foundation) for 35 cents per cubic yard, with the asphalt concrete face or outer core not to exceed 20 cents per square foot. Even with the extra large cross-section necessary it would appear that in the section of the great arid West especially referred to in the paper, if not elsewhere, this mode of building storage reservoirs would be both economical and permanent, when properly planned and executed.